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A correction technology of antenna array atmospheric phase disturbance base on GNSS

Xiping XUE[(1)], Hongbo ZHANG [(1)], Yan SU, Xinying ZHU, and Fang WANG[(1)]
Key Laboratory of Lunar and Deep Space Exploration, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100101, China
e-mail:xuexp@nao.cas.cn;suyan@nao.cas.cn;zhanghb@nao.cas.cn;zhuxy@nao.cas.cn;wangf@nao.cas.cn

Antenna arrays have become a key technology in radio astronomy and deep space exploration. The performance of antenna arrays largely depends on the signal-to-noise ratio of each antenna, the accuracy of phase difference estimation between signals, and the precision of phase correction. Phase correction accuracy is one of the primary factors affecting the overall performance of antenna arrays. Due to interference from the Earth's atmosphere, phase fluctuations in each antenna signal result in poor correlation between antenna signals, which is the main factor limiting the accuracy of antenna array phase estimation and correction. Therefore, atmospheric phase disturbance correction technology is a critical component of antenna array research. Effective atmospheric phase disturbance correction techniques can significantly enhance the reception performance of antenna arrays.

There are three atmospheric phase disturbance correction technologies: phase correction based on microwave radiometers, phase correction based on global positioning systems (GPS), and phase correction based on calibrated antennas. The microwave radiometer-based correction technology offers the best timeliness, but its equipment cost is relatively high. The calibrated antenna-based correction method provides good correction performance, but it can negatively impact the overall performance of the antenna array. The GPS-based correction technology has the lowest cost; however, achieving high correction accuracy requires longer observation and calculation times. To address these limitations, an atmospheric phase delay correction method based on the carrier phase difference of global navigation satellite system (GNSS) receivers is proposed. This method builds upon GPS-based correction technology and is tailored to the practical needs of ground stations.

The receiving equipment at both stations uses a highly stable atomic clock as the external frequency standard. The method employs the single difference of the carrier phase and the double difference on the epoch between the two stations, deducting the phase change caused by satellite movement through the use of ephemeris data. After cycle slip detection and correction, satellite orbit errors and station coordinate errors are eliminated through long-period fitting. Finally, real-time measurement of ionospheric and tropospheric disturbances at both locations is achieved using dual-frequency or multi-frequency signals. To validate the real-time correction method for atmospheric phase disturbances at different locations, a set of Global Navigation Satellite System (GNSS) receiving equipment, including Beidou, GPS, and Galileo systems, was deployed at Kunming Station and Miyun Station of the National Astronomical Observatories of the Chinese Academy of Sciences. The correction results using the third frequency, derived from dual-frequency carrier phase measurement data, show that the root mean square (RMS) of atmospheric phase disturbance after correction reaches 2.0 mm under various weather conditions. This demonstrates that the method is effective for atmospheric phase disturbance correction in antenna arrays used for radio astronomy and deep space exploration.